NASA TECHNICAL TRANSLATION NASA TT F-15,174

ON THE RELIABILITY OF RESULTS FROM THE TOWER TEST FOR FREE FLIGHT TESTS

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(NASA-TT-F-15174) ON THE RELIABILITY OF RESULTS FROM THE TOWER TEST FOR FREE FLIGHT TESTS (Kanner (Leo) Associates) 15 p HC $3.00 CSCL 01B

N74-11827

Unclas
G3/02 22752

Translation of "Über die Verlässlichkeit von Ergebnissen aus dem Dornversuch für Freiflugversuche," Report on the Third Meeting of the DGLR-Symposium, Flight Testing Technology: Reliability of Results Derived from Simulation in Comparison with Results of Actual Flight. (Meeting held at Bremen 28 April 1972) N73-19005 through N73-19011. Deutsche Gesellschaft für Luft- und Raumfahrt (W. Ger.) -- DLR-Mitt-72-18; dated October 1972, pp. 79-92

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 NOVEMBER 1973

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT F-15,174		
4. Title and Subtitle ON THE RELIABILITY OF RESULTS FROM THE TOWER TEST FOR FREE FLIGHT TESTS		5. Report Date November 1973 6. Performing Organization Code
7. Author(s) H. Görlich VFW - Fokker GmbH, Bremen		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates, P.O. Box 5187, Redwood City, California 94063		11. Contract or Grant No. NASw-2481 13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Über die Verlässlichkeit von Ergebnissen aus dem Dornversuch für Freiflugversuche," Report on the Third Meeting of the DGLR-Symposium, Flight Testing Technology: Reliability of Results Derived from Simulation in Comparison with Results of Actual Flight. (Meeting held at Bremen 28 April 1972). N73-19005 through N73-19011. Deutsche Gesellschaft für Luft—und Raumfahrt (W. Ger.) -- DLR-Mitt-72-18; dated October 1972, pp. 79-92.

16. Abstract

The determination of aerodynamic characteristics of aircraft while mounted on a fixed column is discussed. The construction of the test equipment to measure pitching and rolling moments is described. The advantages of using such a method as a complement to flight tests are outlined. Specific examples of tests conducted and the results obtained during captive tests are analyzed.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	~~14~~ 16	3.00

ON THE RELIABILITY OF RESULTS FROM THE TOWER TEST FOR FREE FLIGHT TESTS

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Prior to the beginning of free flight tests of VTOL aircraft, SG 1262 and VAK 191 B mooring towers were used for preparatory tests under conditions as close as possible to operational ones. The aircraft remained moored to the ground. /79*

The use of such mooring towers or pylons of necessity resulted in a limitation of freedom of movement. In the case of the testing of the SG 1262 and the VAK 191 B, the mooring tower permitted movement about the center of gravity only with a limited angular range. For the SG 1262, a hydraulically retractable column with ball and socket joint was chosen; the point of support was approximately at the center of gravity. In the case of the VAK 191 B, such a mooring to the ground was not possible. In its place, a trapezoidal kinematic design was used that also permitted movement about the center of gravity (Fig. 1).

Limitation of pitch and roll movements was obtained by means of mooring cables with built-in shock absorbers. Movements about the vertical axis were not limited.

The utilization of mooring towers resulted from the requirement:

1. To test the coordination of all systems under conditions as real as possible with power plants operating and with the risk confined to a minimum.

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*Numbers in the margin indicate pagination in the foreign text.

2. To test the stability and controlability about the longitudinal, transverse and vertical axis.

In the following, we will discuss the problems that result from an evaluation of stability, the dynamics of transient processes and of controlability. /80

When using the results from the tower tests for an attempt to give information regarding the behavior in free flight, the fact must be taken into account that partly considerable differences exist between the conditions at the tower and in free flight. This results in limitations with respect to the transferability of findings.

For the evaluation of results from tower tests, special attention must be paid to the following points:

Tower Effects

In order to avoid recirculation and to create freedom of movement, the tower must lift the aircraft as high as possible above the platform. Due to its geometric shape, it possesses a certain life of its own in the form of elastic deformations with definite characteristic frequencies. In addition, there are friction forces that can change considerably, depending on the position of the aircraft.

Recirculation

Blast deflectors were erected in order to avoid recirculation effects, but they are effective only with an optimal design. In the case of the VAK, the blast deflectors were sealed once more with steel plates, which considerably cut down on the recirculation and blast effects.

Lacking Wind Effect

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It was not possible to study the effect of aerodynamic moments on the phenomena of motion at the tower; the jet-induced forces and moments can also be different at the tower. Even the SG 1262, a tubular structure stabilized for attitude and equipped with five lift engines proved during free flight to be extremely wind-sensitive during yawing in spite of lacking aerodynamic features. It was not possible to study these effects at the tower.

Unrealistic Thrust Adjustment

The only result of adjusting to a constant thrust is that it will only approximate the weight of the aircraft, because the weight constantly decreases by way of fuel consumption. In free hovering flight, the ratio of thrust/weight = 1 is constantly maintained.

These points essentially form the reason for differences between the possible deviations of results from tower tests and free flight. What is the order of magnitude of these differences?

For this we will use the example of the longitudinal control attitude of the SG 1262 during jump signals (Fig. 2). To this end, the transient time and the amount of overtravel were specified, resulting in the following:

$$t_{95} = 1.4 \text{ sec, slight overtravel of } .5^\circ$$

The pitch control attitude of the SG 1262 in free flight is given in Fig. 3 for comparison.

There are only slight differences to be discerned in an accurate comparison of transient dynamics with the results from the tower tests. From this example, the fact could be deduced that the effect of greater wind velocities on dynamics is negligible.

A comparison of roll control behavior at the tower and in /82
free flight results in a slightly different picture. The time response at the mooring tower, as depicted in Fig. 4 for jump signals, could also be detected with relatively small deviations in stationary hovering flight, i.e., with an absolute minimum of wind activity. A totally different behavior could be observed, however, during airflow coming from the side (Fig. 5). In this diagram, the roll control behavior in the case of jump signals at lateral components of velocity of approximately 35 km is plotted. It can be gathered from this that overtravel, which was negligibly small at the tower on account of small wind velocities, could attain unduly high values in free flight.

The ensuing danger of PIO had to be checked by means of reducing the flight range. For this reason, the connection between wind velocity and induced disturbing moment was first established. Due to the fact that the effect of disturbing moments on the aircraft causes a corresponding reaction at the control, the disturbances could be measured at the aperture angle of the control nozzles. In this manner, the connection as plotted in Fig. 6 was established. Many free flights were, however, required for this purpose, since each test resulted in only a few measuring points. The measuring points are scattered due to the different thrust adjustments in each case, on which in turn the maximum bleed control moments depended.

The disturbing moment, determined as a function of the side wind, was caused by the intake impulses of the vertically mounted power plants. Due to the fact that wind velocities of this kind did not occur at the tower, the attendant disturbing effects could not be studied. Only when the results from free flight tests were available could they be used for the evaluation and fixing of the flight range.

Another effect that could not be studied at the tower was the influence of the increasing amount of air flow on the trend of the angle of bank. By using a PD control, the effect of an external disturbing moment indicates a reduction of the angular position signal; for the same reason, subsequent to a reversed angular position, an angle, increased at first, is occupied. /83

The examples noted have demonstrated that especially the roll control behavior in free flight can furnish results quite different from those at the mooring tower. Whereas in the case of the SG tests it could be determined that the time response, at least in still air, during free flight and at the tower was nearly identical, this could no longer be determined in the case of the VAK tests.

In Fig. 7 the pitch control attitude of the VAK 191 B is shown, as established at the tower for jump signals.

Here, it is clearly evident that even for identical control signal amplitudes, different transient processes occur, the causes of which can not be clearly discerned. The fact that the effects in the roll control behavior of the VAK were similar finally resulted in the tower only being used for tests of the control system, with the tests mainly limited to a checking of signs. Thus, the qualitative evaluation of system behavior is only possible in free flight tests.

In addition to the noted test, the mooring tower is, for instance, also suited to the following problems:

Control sensitivity and its calibration.

Preliminary tests regarding the controlability of the emergency control in case of a failed controller, as well as reversal effects.

Especially for the last point, the mooring tower offers important advantages over free flight tests, because here the safety of man and machine is of primary importance. On the other hand, there are problems for which the mooring tower is only suitable to a limited extent or not at all, as for instance for effects of breakdowns of the control and steering system or elevator controlability.

However, as has been shown by the example of stability /84
and controlability, the fact must be taken into account for an evaluation of results that in most cases several disturbances will overlap. At the tower they encounter partly different causes than in free flight. Agreement throughout was effected by means of a rather good knowledge of these conditions. For the most part, however, coming to grips with these disturbances offers great difficulties. In addition, the possibilities of studying certain problems at the tower are limited.

Summary

Using several examples from tests of the hovering frame SG 1262 and the VAK 191 B, it is shown to what extent agreement can be attained with comparable results from tower and free flight testing. It is shown that the transient behavior at the tower is differently affected by different disturbance effects, the understanding of which would cause partly excessive effort. Additionally, as the freedom of movement is also limited, the evaluation of stability and controlability by tower testing

is greatly limited. On the other hand, the tower offers great advantages for studies where the safety of man and machine is paramount.

Summary Outline of Diagrams

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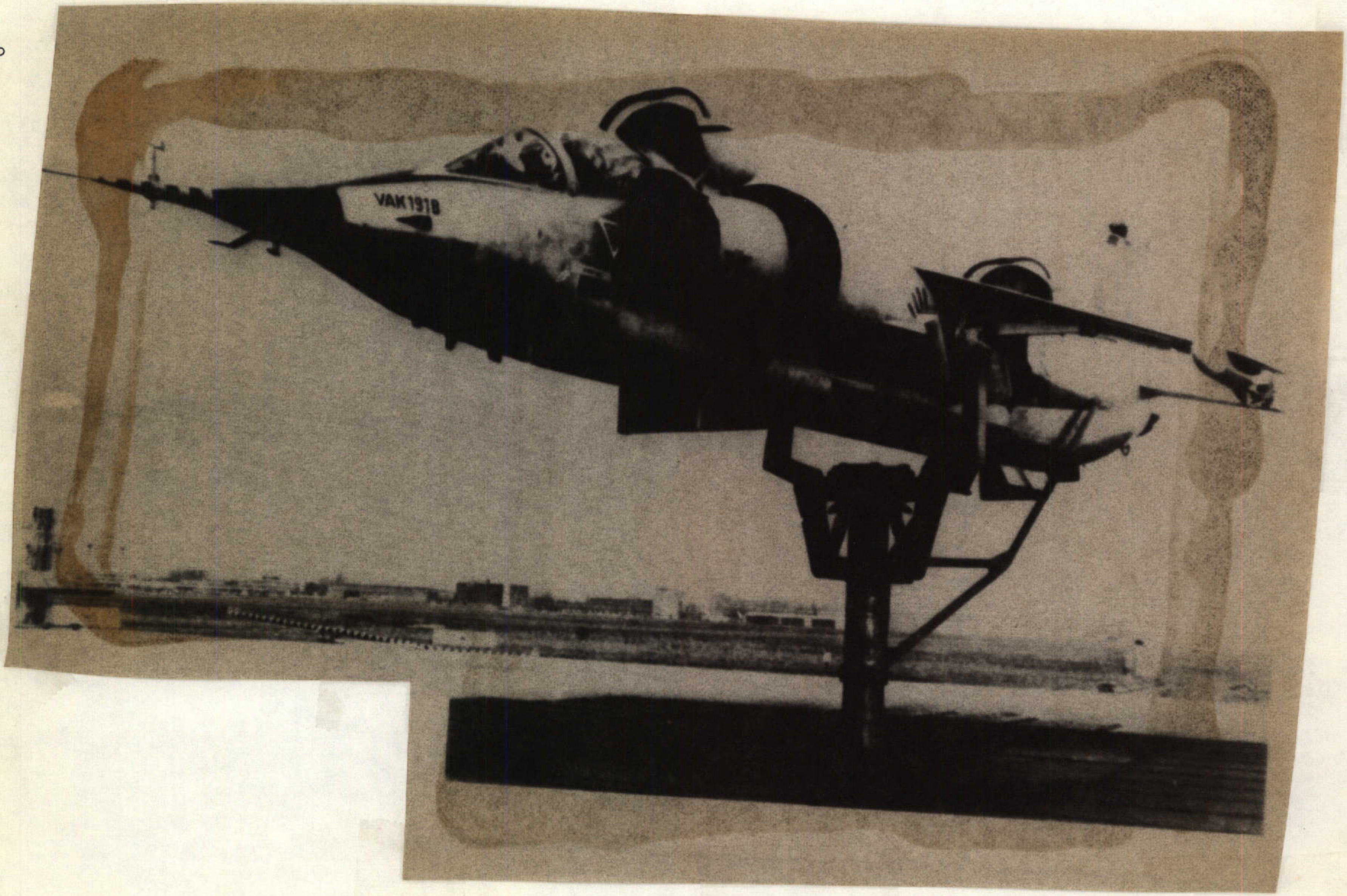

Fig. 1. Mooring tower VAK 191 B.

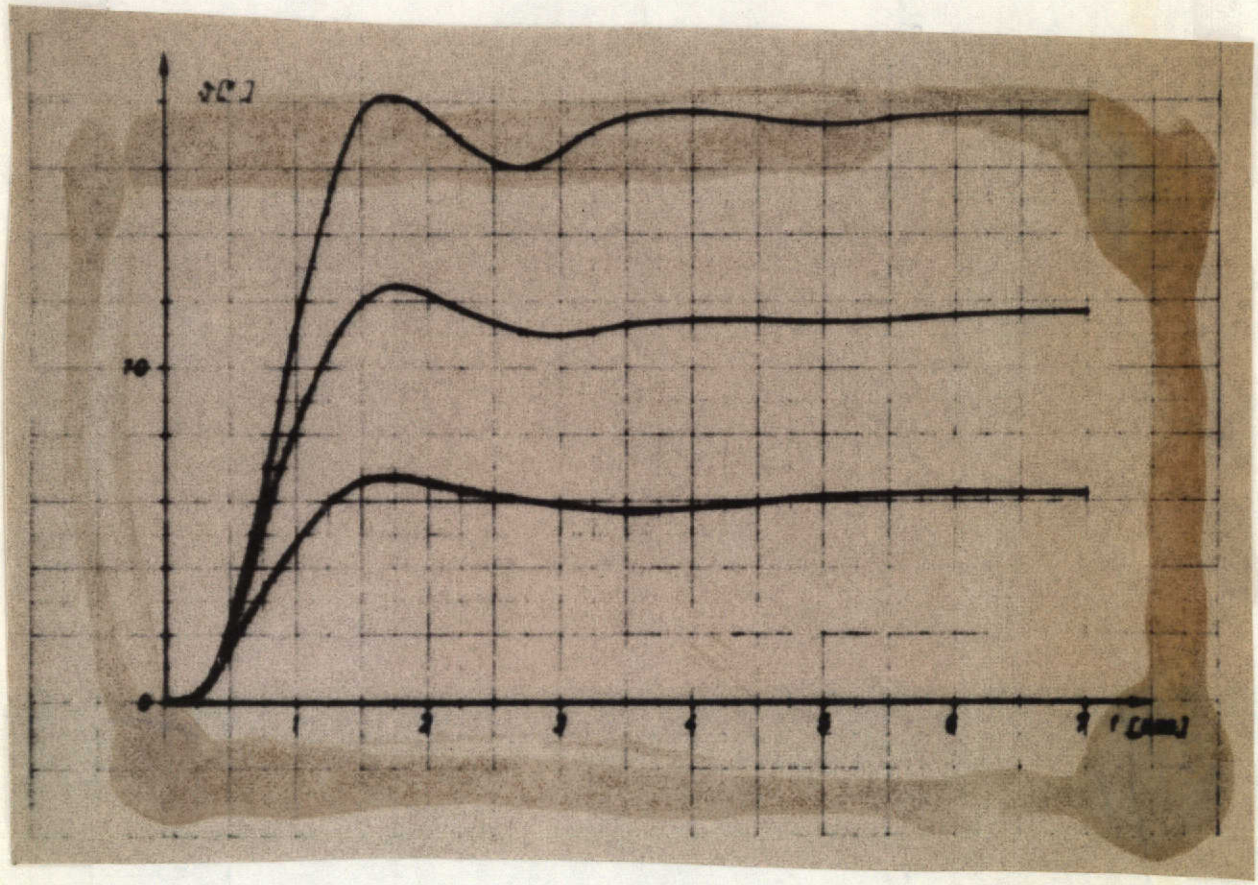

Fig. 2. Time response at the mooring tower of SG 1262
for jump pitch control signals.

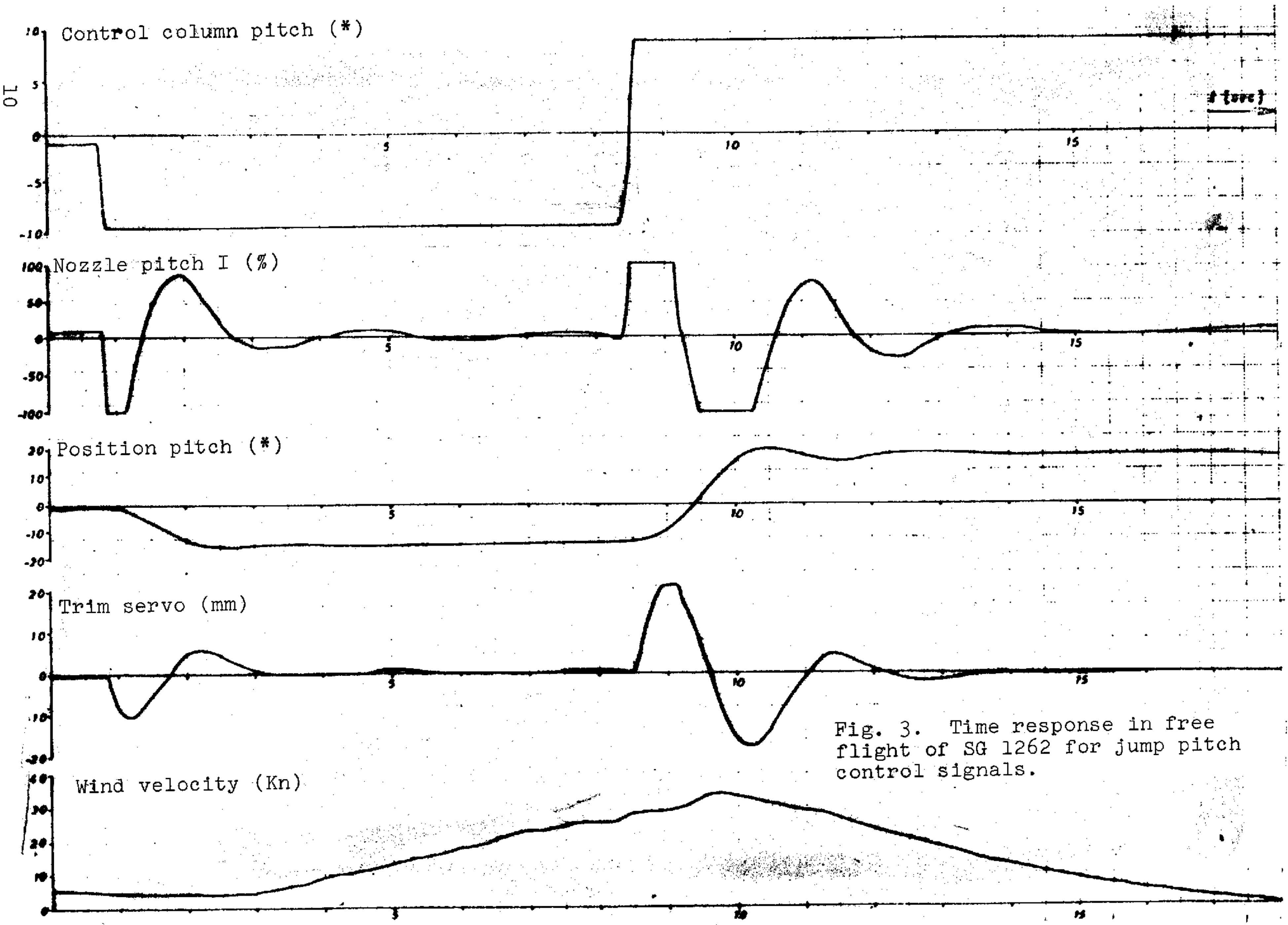

Fig. 3. Time response in free flight of SG 1262 for jump pitch control signals.

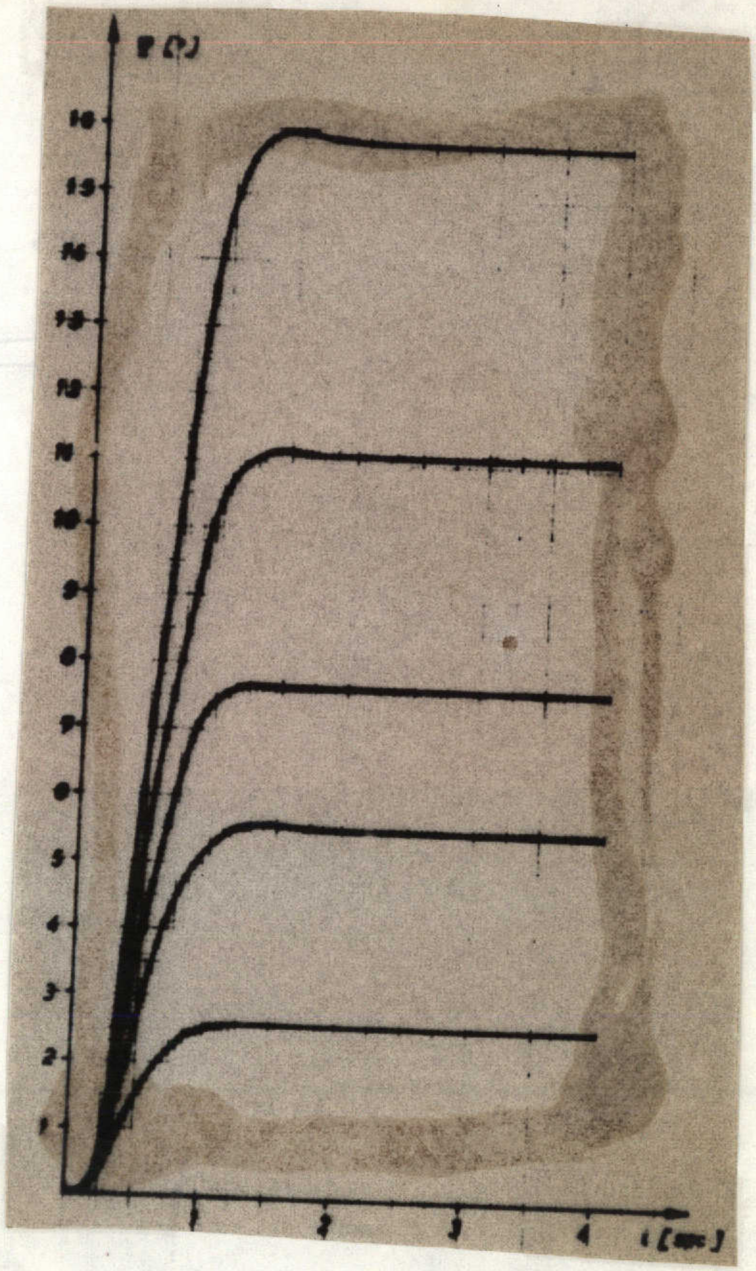

Fig. 4. Time response at the mooring tower of SG 1262 for jump roll control signals.

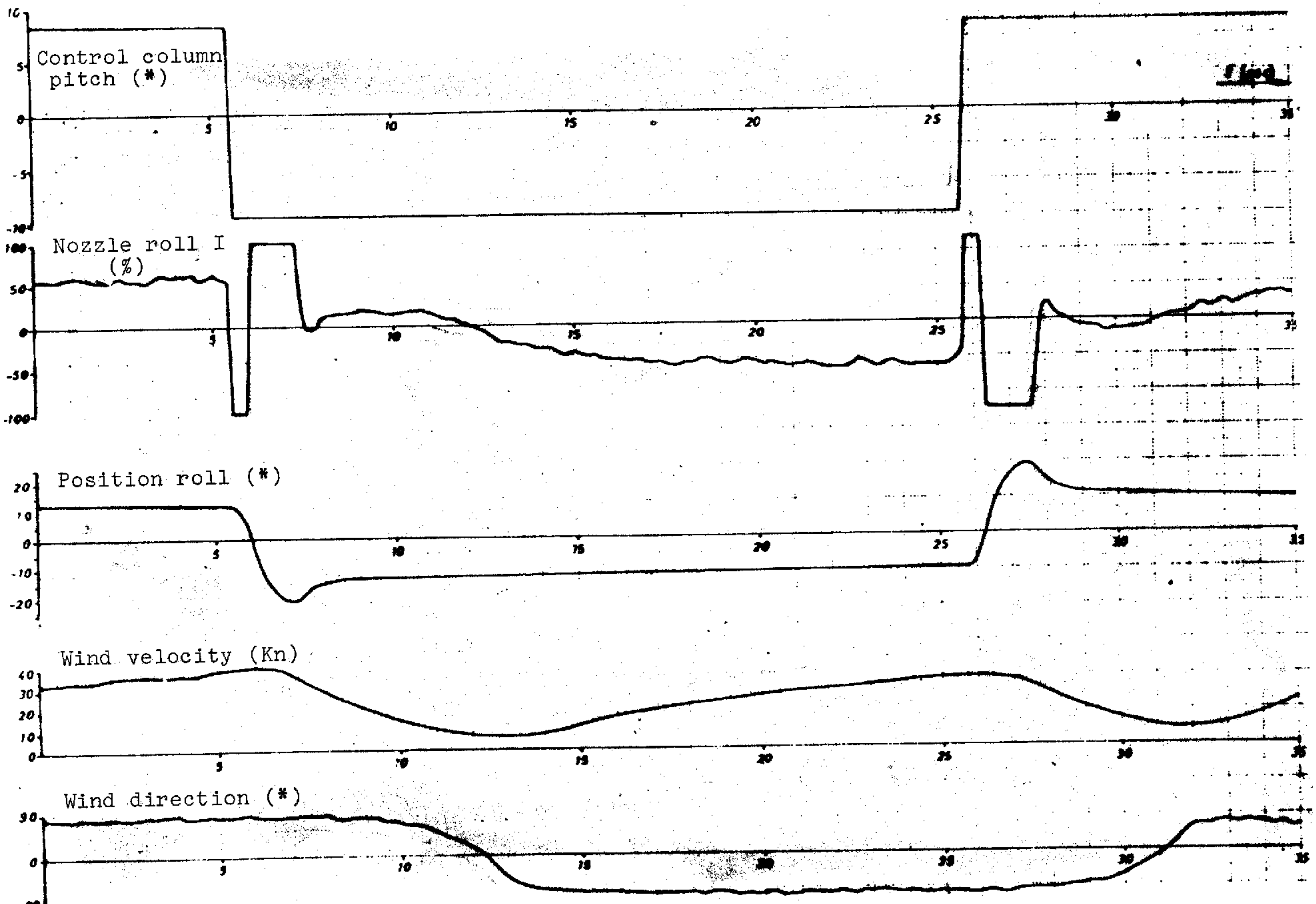

Fig. 5. Time response in free flight of SG 1262 for jump roll control signals with greater lateral component of velocity.

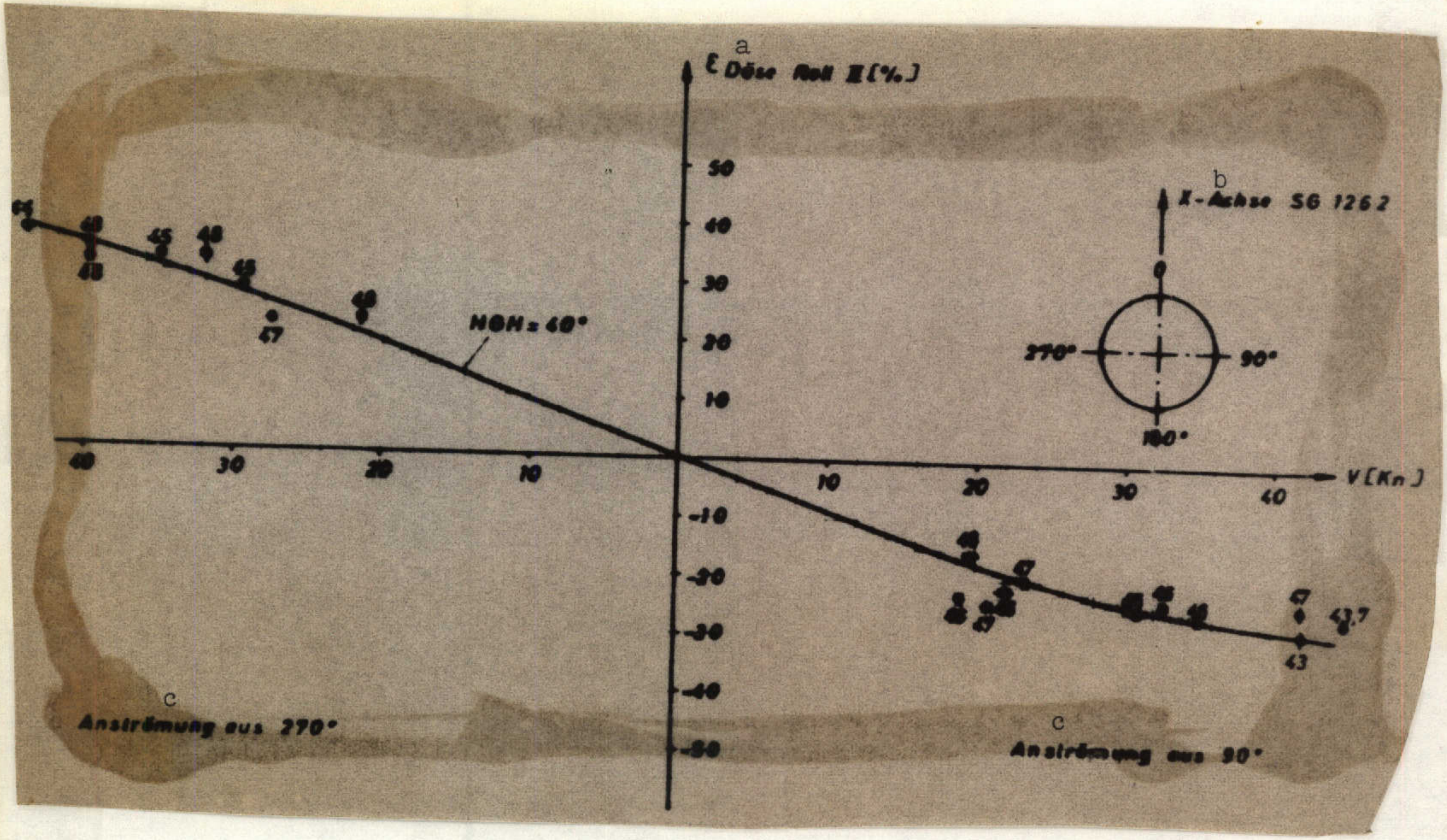

Fig. 6. Roll disturbing moment as a function of side wind activity, measured at aperture angle of control nozzle.

Key: a. Nozzle roll II (%)
b. Axis
c. Wind blowing from

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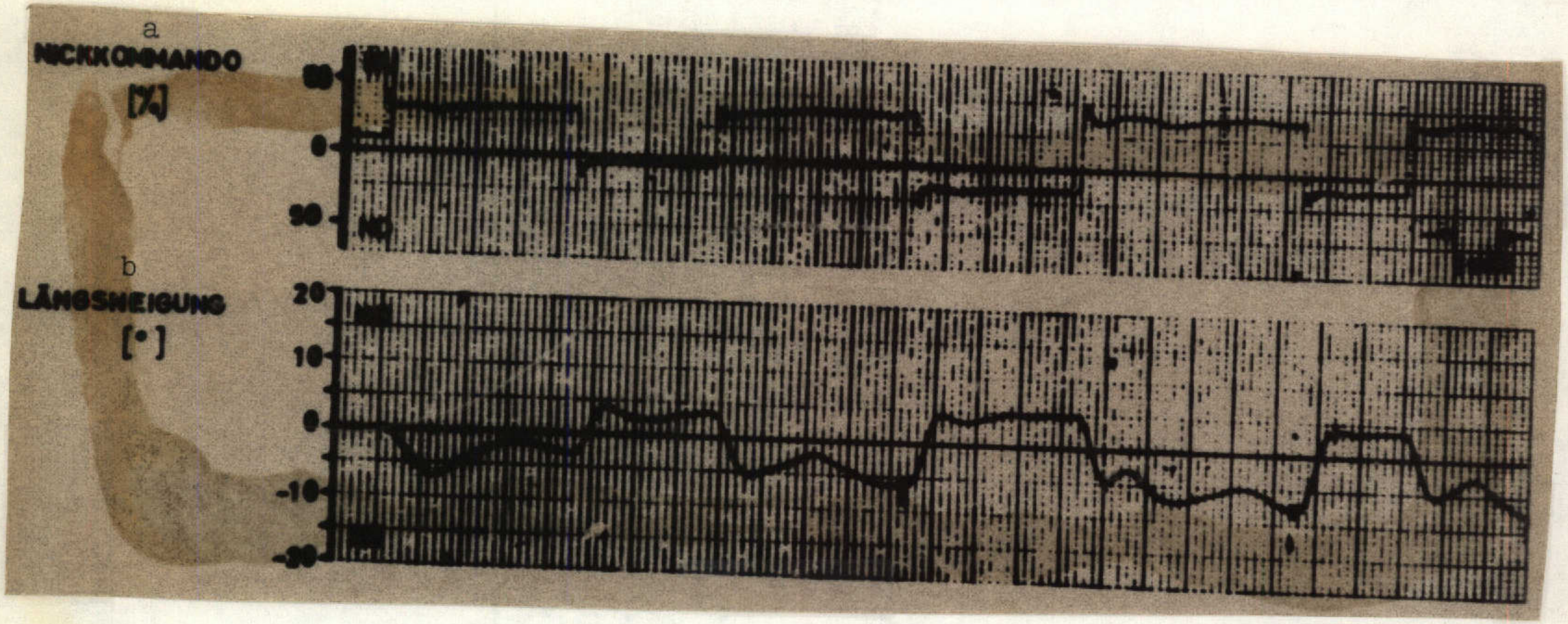

Fig. 7. Time response at mooring tower of VAK 191 B for jump pitch signals.

Key: a. Pitch signal (%)
b. Longitudinal slope (pitch)